SECOND YEAR REPORT OF WORK COMPLETED UNDER NAGW-3674 FOR THE PERIOD

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The Earth System Science Laboratory
The University of Alabama in Huntsville
Huntsville, AL 35899

Dr. Michael E. Botts

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The Interuse Experiment, under the direction of Dr. Mike Botts at UAH/ESSL and funded under the NASA Pathfinder program, is working to improve the usability of satellite swath data within end-user tools, and to advance capabilities within end-user tools for comparative analysis and visualization of multiple data sets of earth-based sensors. One major activity of the Interuse effort is the adaptation and testing of the SPICE Observation Dynamics Model (ODM) software for earth-based systems. The SPICE ODM was developed within the planetary science community by the NASA/JPL Navigation and Ancillary Information Facility (NAIF) and provides a common library and API for accessing and geolocating all satellite and aircraft data.

In addition, the Interuse Experiment is focusing on improving the interusability of EOS and Pathfinder data for the end-user by (1) improving the capabilities for comparative visualization and analysis of multiple disparate data sets within end-user tools, and (2) improving the end-user's capabilities for querying, subsetting, and retrieving coincident data from within available data bases.

A. Coordination with JPL/NAIF and JPL/IAS

The activities being undertaken at UAH under this grant have been heavily linked and coordinated with ongoing activities at JPL. The related activities at JPL were funded through RTOPS and include adaptation of existing software and expertise to the EOS/Pathfinder Interuse needs. The JPL teams include the Navigation and Ancillary Information Center (JPL/NAIF) which has the role of adapting SPICE navigation software to earth based sensor systems, and the Image Analysis Systems group (JPL/IAS) which is working to extend and adapt SPICE-based application software developed for the Planetary Sciences. All activities at UAH and JPL related to these Interuse studies fall under the direction of the UAH PI. It is difficult to completely separate the activities and work completed at JPL from that at UAH, since these are strongly coordinated and intermingled.

B. Activities Completed or Ongoing

Replacement of Mary Anne Buvens with Ron Phillips

Ms. Buvens left the UAH Interuse team in September in order to take care of family matters and was replaced immediately by Ron Phillips. Mr. Phillips is a very strong programmer in C, C++, and FORTRAN, as well as within the visualization and graphics domains of X/Motif and Open-GL. Mr. Phillips has been a major boon to the development efforts of the UAH team.

Incorporation of AVHRR and OTD sensors into SPICE

The AVHRR sensor was brought under the SPICE system by the JPL/NAIF team. Because of the limited access to low level AVHRR data, the initial kernels have yet to be fully tested. More complete testing and kernel generation of the AVHRR kernels will take place at UAH within the third year activities. One of the major lessons learned regarding the generation of complete kernels for heritage sensors is that much of the ancillary data and information required is very difficult to locate and has rarely been archived well. A significant amount of "detective work" is often required in order to adequately describe the complete geometric and dynamic state of these heritage sensor systems. These challenges often add several months to the effort of bringing a new sensor into the SPICE realm. Bringing new sensors where such information is still readily available, is relatively straightforward relative to older sensor systems.

As an example of the problem, Ken Knowles of the University of Colorado has related an experience he had in trying to find ancillary information required to geolocate the OLS sensor. After several fruitless months of trying to track down a particular instrument parameter, Ken, on an unrelated trip, stopped by chance into someone office who had had some contact with the OLS sensor activities. After digging

through several old notebooks, the person was finally able to find where he had written the value of this important parameter in the margin of one of the pages. For future refinement and application of swath data, it is vital that all parameters required to describe the geometry and dynamics of a sensor system, be archived and defined in a standard manner. SPICE provides one such standard. The primary challenges have been and will continue to be in defining the specifics regarding the geometric characteristics of the instruments.

The Optical Transient Detector (OTD) sensor differs from other earth-based sensors brought into SPICE in that it is a very rapid imager rather than a scanner, and also employs custom on-board processing to distinguish and transmit lightning events every 2 msec. Background images are also taken and transmitted every minute or so when transmission bandwidth is available. The spacecraft inconsistently rotates and wobbles about the nadir point, while the sensor has an odd shaped footprint. This requires a high volume of attitude data and makes correction and refinement of the attitude difficult. The use of SPICE for OTD has been highly successful from day one of the mission. The SDP toolkit which was being tested for OTD in parallel to the SPICE effort has yet to provide any geolocation of OTD as of this date.

Extension of SPICE to handle non-inertial coordinate frames of reference

The planetary science spacecraft navigation community primarily uses an inertial frame coordinate system which is common for all solar bodies. The earth system satellite community often deals with a more earth-centered frame of reference. Although transforms are possible between these coordinate frames, as shown by the SPICE implementation of SSM/I, it was decided that there would be future conveniences and benefits (particularly with regard to the addition of aircraft), in generalizing the potential frames of references available to SPICE. The implementation of OTD into SPICE was a particular driver for this extension of SPICE. This activity was primarily the effort of the NAIF group at JPL. The full implementation of these general frames of reference is being tested at UAH and will be more fully tested with the third year implementation of SPICE with aircraft systems. This is a major extension of SPICE by the NAIF team which will have significant benefits for the planetary and earth science community alike.

Development of a model for interuse of data within a space-time continuum

Ron Phillips of the Interuse team at UAH has been adapting and testing a time-space model for incorporation into visualization and data management tools. This software allows any number and type of data set to be integrated onto a 3D globe or 2D map projection, and to interactively advance all data sets through time for the purpose of determining data coincidence or for comparative visualization. Data sets can consist of satellite or aircraft swath data, gridded and projected data, station or path data, and events. Essentially, any data that can be tagged with or transformed to latitude-longitude-altitude-time coordinates can be accounted for. Currently referred to as GLOBE, the software is being refined and tested to meet the needs of the OTD research team. These capabilities are being developed such that they can be easily incorporated into any visualization and analysis tool to provide improved capabilities for geolocation and interuse of disparate data. Through funding from the EOS Prototyping NRA grant, efforts are underway to incorporate these capabilities into LinkWinds. Under the Interuse Experiment, efforts to move this functionality into IDL will begin within the next month.

Development of capabilities for querying data sets based on coincidence

Spatial searching and coincident searching have been demonstrated using SPICE for search of swath data combined with the GLOBE space-time tool. The concept presented and demoed is one in which an end-user could from within a standalone tool define and package a data request for subsetted swath data based on the desired time and geographical area of interest. The area of time of interest could be determined based of comparative visualization of a wide variety of time-varying satellite sensors, gridded products, paths (e.g. hurricane tracks, aircraft tracks), or events (e.g. volcanic eruptions, tornadoes, or lightning flashes), all of which can be synchronized and progressed through space and time (Figure 1). One of the visions of this tool is that the user will be able to (1) either interactively or automatically determine

coincidence between data sets or to spatially search for swath and gridded data of interest, (2) define the subset of interest, (3) package this request as an object for submission to the DAAC (via DCE or CORBA), and then (4) receive only that subset of the data in which s/he is interested.

Highly positive discussions regarding setting up an end-to-end testbed with the HAIS ECS teams have been taking place for the last month. These discussions have been with Mark Settle, Michael Burnett, Mark Huber, and Tim Gubbels, and have centered around a testbed in which SPICE and GLOBE would provide a front-end object-request broker and subsetting capabilities within future versions of the DAAC.

The Optical Transient Detector Mission

The Optical Transient Detector (OTD) mission is serving as one of the testbeds for many of the capabilities being developed under the Interuse Experiment. It also provides a stepping stone for potential interuse activities within the upcoming TRMM Mission. Under this effort, SPICE "kernels" are being generated for the Microlab satellite and OTD sensor, allowing interactive determination of the OTD footprint at any time, as well as rapid geolocation of any OTD event or background image (Figure 2). The SPICE navigation/ geolocation system has been performing well from the onset of the mission, and is being used within the entire data production, data query, and visualization path. The SDP geolocation toolkit which was being tested for OTD in parallel with the SPICE effort has yet to be successfully implemented. The efforts of Bill Taber at NASA/JPL/NAIF and Bob Creasey at UAH/ESSL have been vital to the success of SPICE within the OTD mission.

The OTD team with support of the Interuse Team has been utilizing GLOBE and SPICE to geolocate and integrate OTD background and lightning event data with GOES-meteosat composite imagery, US gridded precipitation data, US ground-strike lightning events, LDAR lightning events, and SSM/I. In addition to comparative visualization, the OTD implementation of GLOBE will allow determination of coincidence between these data sets and can provide data retrieval and subsetting of OTD data. Ron Phillips has been responsible for programming of GLOBE and its implementation for OTD.

Interactive Correction of SPICE Kernels

Ron Phillips has implemented an interactive tool that allows correction of spacecraft clock errors and refinement of satellite pitch, roll, and yaw. As the user dials changes to timing, pitch, roll, or yaw, these changes are immediately reflected in the mapping of the instrument geolocation onto the globe (Figure 3). These corrected values can then be used to correct a short sequence of the sensor data or can be collected over long time sequences in an attempt to determine and correct systematic errors in the spacecraft navigation ancillary data. This highlights a very important capability of SPICE for easy correction and refinement of satellite data through modification or augmentation of the SPICE kernels. This capability will be instrumental in correcting some days of the OTD sensor in which the satellite clock and attitude were particularly bad (with timing errors of 200-300 seconds) and for some days when navigation ancillary data were completely lost in transmission. It is presently being used by the OTD team to look for systematic errors in the attitude data.

Interuse Lessons Learned Document

The Interuse teams from UAH and JPL actively participated in the Pathfinder Interuse Conference held in Washington D.C., March 30 - April 1, 1994. In addition to presentation on the Interuse Experiment, the Conference included an Interuse Breakout Session chaired by Dr. Botts. The breakout session included very active participation from many scientist and computer technicians and resulted in a healthy discussion of lessons learned and important future directions. The results of this breakout session, as well as input from workshops sponsored by the Interuse Experiment, were documented within the Science Parameter Interuse section of the Pathfinder Lessons Learned White Paper report [Maiden *et. al.*, 1994]. Dr. Botts served as editor and prime author for the Interuse section.

C. Trips, Workshops, and Conferences

A major part of the ongoing activities of the Interuse Experiment involved investigating, prototyping, and presenting new, advanced concepts for improving the technology for the interuse of EOS data. One of the largest challenges is that of convincing instrument teams, data system architects, and scientists to consider improved approaches that deviate from business-as-usual. It has also been challenging to fully understand the needs of the scientist in this era of rapidly changing technology and to adapt these improved techniques to meeting those needs. Thus, a significant amount of effort within the Interuse Experiment has been directed toward the exchange of information between the Interuse team and the technical and scientific community. This is perhaps still the weakest link in the Interuse Experiment activities.

4th Interuse Workshop

(Boulder, CO - July 6-7, 1994). The 4th Interuse Workshop, organized by the UAH Interuse Team, focused on the scientific requirements of Interuse and introduced the Interuse activities and software to a select group of EOS scientists. The 33 attendants included prominent earth scientists, computer technologists, ESDIS and ECS personnel, the President and the chief developer for Research System Inc (developer of IDL), and the UAH and JPL Interuse teams.

Some of the main points that came out of the workshop were:

(1) there is a clear need for data levels 2 and 1 to be archived and easily accessible where possible

(2) statistics and data quality must be provided for L3 data, including quality of geolocation and perhaps the location within the pixel of the statistical mean

(3) information regarding time of sampling (including statistics) must be provided in L3 data, and local time should be available or derivable for any L2 and L1 data

(4) there is a need for the end-user to have access to or be able to derive geometric information beyond lat-lon (e.g. incidence angles, look angle relationships, etc). It is not always predictable, a priori, what the required relationships will be

(5) there is too much instrument-specific focus and not enough cross-sensor investigation

(6) scientists view: the EOS system is being pushed-driven by data producers and instrument teams; EOSDIS/data producers view: the system is too pull-driven by the numerous demands by the end-user

(7) there are significant benefits to all tool makers and scientists to talk and work together

(8) Nutshell statement: "different users want different things"

AISRP

(Boulder, CO - July 11-13, 1994). Dr. Botts presented the Interuse Experiment issues and directions to the NASA AISRP software development group, funded under Joe Bredekamp.

JPL

(Pasadena, CA - September 10-14, 1994). Meetings between Dr. Botts and the JPL/Interuse teams to discuss directions and exchange technical information.

Visualization '94

(Tyson's Corner, VA - October 17-21, 1994). Dr. Botts chaired a Panel Session entitled " Challenges and Opportunities for Visualization with NASA's EOS Mission to Planet Earth" in which ideas for meeting the visualization and interuse needs of EOS were presented to and discussed with the visualization developer community.

EOSDIS NRA-CAN Workshop

(Landover, MD - January 23-27, 1995). The activities of the Interuse Experiment were presented at the first EOSDIS NRA Workshop. The EOSDIS NRA prototyping program will serve as one of the mechanisms for the transition of ideas and software from the Interuse Experiment into the EOSDIS.

JPL

(Pasadena - February 5-7, 1995). The UAH Interuse team of Botts, Creasey, and Phillips met with JPL Interuse teams of Lee, Weidner, Acton, and Taber in order to prepare for the OTD launch, to discuss directions of Interuse activities, and to allow the UAH team to become more familiar with the SPICE and Interuse software developed at JPL. In addition to group meetings, Creasey met extensively with Taber to delve into SPICE software and concepts, while Phillips met with Lee and Weidner to learn more about OoSPICE and the Interuse Mapper software.

IS&T/SPIE Symposium on Electronic Imaging: Science and Technology

(San Jose - February 5-10, 1995). Dr. Botts wrote a paper entitled "Libraries and APIs to Assist the NASA/EOS and General Earth Science/GIS Visualization Developer" and presented the challenges of meeting the visualization and interuse needs of EOS, and the activities being undertaken by ESDIS and the Interuse Development teams to assist developers in meeting the visualization needs of EOS scientists.

Data Management Working Group

(Landover, MD - May 4-5, 1995). Dr. Botts was invited to the DMWG in order to present and demo software and concepts for spatial query of EOS data sets using observation dynamics models (ODM). Within the Spatial Query Splinter Group, the feasibility of spatial and coincident query of EOS data was demonstrated using SPICE and the GLOBE model developed by the UAH Interuse team. The concept presented and demoed to the group was one in which an end-user could from within a standalone tool define and package a data request for subsetted swath data based on the desired time and geographical area of interest. The area of time of interest could be determined based of comparative visualization of a wide variety of time-varying satellite sensors, gridded products, paths (e.g. hurricane tracks, aircraft tracks), or events (e.g. volcanic eruptions, tornadoes, or lightning flashes), all of which can be synchronized and progressed through space and time.

AGU Spring Workshop

(Baltimore, MD - May 29-June 2, 1995). Dr. Botts presented a presentation entitled " Improving the Use and Interuse of Pathfinder and EOS Data Sets" within the Pathfinder Session. In addition to a discussion of interuse issues, and the Interuse Experiment directions, a video was presented showing the application of the SPICE ODM and the GLOBE model for three activities: search for coincident data, the visualization of OTD data, and the correction of clock, pitch, roll, and yaw errors for the OTD mission.

IDS Land Surface Evapo-Transpiration Workshop

(GSFC - June 1-2, 1995). Dr. Botts was invited to the IDS ET Workshop to present the Interuse software and directions. The presentation was similar to that presented at the AGU session and was well received by the Interdiscplinary scientists and other participants. After the presentation and unaware of ongoing discussions with others at HAIS, Tim Gubbels, the prototyping manager of HAIS, approached Dr. Botts

about establishing an end-to-end testbed prototyping activity for spatial and temporal query and subsetting using SPICE and GLOBE as a frontend to the DAAC.

Scheduled Events

Several interuse presentations by Dr. Botts have already been scheduled for the remainder of the 1995 year. These include the following:

LIS Science Working Group, Huntsville, AL - June 5: Presentation and Demo of Interuse Software

2nd EPA International Visualization Workshop, Raleigh, NC - July 26-29: Visualization and Interuse of EOS Data (invited presentation and demo)

European Symposium on Remote Sensing II, Paris, France - September 28: Importance of a Standard Observation Dynamics Model for Earth Observing Sensors

D. Third Year Directions

The following directions for the third year activities will be discussed in more detail in the third year proposal for continued funding:

Continued interaction and transfer of technology to OTD/LIS team

Continued development and refinement of time-space continuum software

Incorporation of interuse software into LinkWinds and IDL

End-to-end testing of data query and subsetting concepts based on data coincidence

Testing of new functionality for flexible coordinate frames within SPICE

Extension and testing of SPICE for aircraft sensors

Tying up loose ends and refining interuse development libraries for SPICE, map projections, binning/gridding, etc.

Testing of interuse concepts within joint satellite-aircraft-ground missions (e.g. TOGA-COARE)

Generation of complete SPICE kernel sets for SSM/I, AVHRR, OTD

Incorporation of other satellite sensors into SPICE (e.g. GOES, OLS, SSM/T, MSU)

Pressing and distribution of interuse CDROMs containing ODM data and software

Further communication of interuse concepts within technical and scientific communities

E. References

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